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THE MEASUREMENT OF FOREST FIRE DANGER IN THE EASTERN UNITED STATES AND ITS APPLICATION IN FIRE CONTROL

A progress report

by

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FOREWORD

This Station is receiving so many requests for detailed information on fire danger rating -- what it is, where instruments can be purchased, installation and operation of fire danger stations, use of fire danger meters, etc. -- that preparation of letters giving adequate information has come to be both expensive and time-consuming. There also is an immediate need for detailed instructions for observers at the 160 fire danger stations operated under general supervision of the Appalachian Station.

Mr. Jemison has prepared this statement to meet these two urgent needs. He has drawn in varying degrees on the work of other investigators in this field some of whom, like the author, have been engaged on this problem for many years. In this preliminary statement it does not seem feasible to attempt to assign credit to any one person for certain ideas presented here; in fact, so many ideas are the product of joint work that individual credit-lines would be difficult to place. The present report should not be considered as the final word on this subject because fire danger rating is as yet barely emerging from the experimental stage and requires further broad-scale testing. A major purpose of this progress report is to insure uniformity in testing procedure.

As only a small number of copies are available, distribution of this report necessarily must be restricted to those actively engaged in fire danger rating or contemplating installation of a rating system. When results of present tests are known, necessary revisions will be made and a printed publication issued for more general distribution.

Constructive criticism will be gratefully received.

R. E. McArdle

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Director

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INTRODUCTION

This technical note describes a method of measuring forest fire danger[2/] and expressing it in numerical classes having definite meaning and calling for definite action. Heretofore it was possible to rate fire danger only in general terms such as "bad", "fairly bad", "not so bad", and the like, with - in too many instances - correspondingly uncertain and indefinite preparation for presuppression and suppression.

The method here discussed is based on intensive study of the factors that influence the ease with which fires start and the rate at which they spread. More than fifteen years ago, in the West, when investigations of fire danger were first begun, ten or fifteen factors were recognized as having an influence on fire danger. Since that time a number of workers have studied the many factors to find out exactly how important each actually is. As a result of recent investigations four key factors have been discovered for eastern mountain forests and three for adjacent coastal plain types.

The former study confirmed a suspicion held by experienced fire control men that relatively small changes in certain factors influencing fire danger caused much larger changes in ease of ignition, rate of spread, and difficulty of control. These small changes defy any dependable estimate by guessing even if the guessing is done by men with considerable fire experience; such changes must be measured. Instruments

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1/For the purposes of this discussion, "Eastern United States" is considered to include New England, the Allegheny and Cumberland Plateaus, Appalachian Mountains and adjacent Piedmont and Coastal Plain. It does not include the deep South, Lake States, or Central States.

2/As this technical note is addressed to technical fire control men, no attempt is made to define the numerous fire control terms used in it. The term "fire danger", however, is used narrowly and refers only to the variable aspects of fire danger such as weather elements and fuel moisture. For complete definitions of this and other terms the reader should refer to, "Glossary of terms used in forest fire control", U. S. Dept. Agr. Forest Service, 1939.

had to be invented for some factors; for others, existing instruments were too expensive for widescale practical use. Means were found to cheapen these instruments in price without reduction in accuracy.

After the discovery of the few key factors having most influence on the increase and decrease of fire danger, the next step was the development of a system for integrating these factors to obtain uniform results in measurements. To do this required careful, on-the-fire study of the conditions prevailing at the time of start of many hundreds of fires and the ease or difficulty of their control. This particular study is still in progress but enough information has been obtained to make possible a reasonably accurate weighting of each fire danger factor so that the most important ones exert the most influence on the final expression of fire danger. The device used to integrate all of the fire danger factors is called a "fire danger meter" and will later be described in detail.

Finally, it was necessary to test this method of rating fire danger over a large area. Preliminary tests have been made, beginning in 1937 and continuing without break on a steadily larger scale to date. At the time this is written, 160 fire danger stations, using the system described here, are in operation in 17 eastern states. About 55 additional stations will be started during the next five or six months.

The system is not yet perfected; further improvements will undoubtedly be made. But the final form of the method now appears to be reasonably well fixed, so that subsequent modifications will probably only be refinements to increase accuracy. In its present stage, therefore, the system is sufficiently advanced to be offered to fire control executives for more extended trial.

The busy fire control official will find the following advantages in this system of fire control measurement:

> It focuses attention on the really important factors influencing fire danger.
>
> It insures that every observer will measure and report on these factors in exactly the same way, thus giving accurate and comparable results even when the fire control executive has to depend for information on men much less experienced than himself.
>
> It catches the small changes in fire danger conditions which may greatly influence the difficulty of fire control.

It provides a means for integrating measurements of the critical fire danger factors into a single numerical class which can be translated into decisive presuppressive and suppressive action.

It not only gives an expression of existing fire danger but also provides a definite means for using fire weather forecasts to obtain a 24-hour warning of future fire danger (with an accuracy of from 70 to 80 percent), thus allowing advance preparations for extremely dangerous days.

It aids, does not displace, judgment of experienced fire control executives. The purpose is simply to help him "guess right" most of the time.

THE PRINCIPLES OF FOREST FIRE DANGER MEASUREMENT

Fire Danger Factors, Their Measurement, and Integration

The "Key" Fire Danger Factors

Fuel Moisture Content. Moisture content of fuels, a controlling fire danger factor, is particularly important in light-weight material such as dead grass, hardwood leaves, weeds, and pine needles. Fire brands ignite this material first and it burns most rapidly.

The moisture content of these light-weight fuels changes rapidly as weather fluctuates, but the relation is so complex that moistures cannot be easily or accurately determined from measurement of atmospheric factors such as humidity, temperature, and evaporation. Experience has proved that even the most experienced men cannot determine changes of a few percent in fuel moisture content which may make considerable difference in inflammability.

One simple and inexpensive way to measure fuel moisture is by means of fuel moisture indicator sticks. Different sizes, shapes, and kinds of indicators are used in the United States but flat slats 18 inches long, made from basswood, Venetian blind stock, have been found to work best in the East. These sticks, when exposed under typical forest conditions, reveal the effect, in one simple measurement, of all controls (the causes) of moisture content, such as humidity, temperature, evaporation, solar radiation, and wind. The fuel moisture sticks do not always indicate the exact moisture content of natural fuel but the relation between indicated and actual moisture is relatively constant. In general, the sticks dry out slightly faster than natural fuel

after a rain and thus give some forewarning of approaching dangerous conditions.

The method of determining fuel moisture consists essentially of exposing under natural conditions a set of three numbered basswood sticks, for which the oven-dry weight has been predetermined, and weighing them currently on a specially constructed scale. This scale shows average moisture content directly.

While the wood sticks provide excellent measures of current changes in the light fuels they do not reflect the cumulative build up of inflammable conditions in heavier fuels, denser "rough", and deeper layers of hardwood leaves resulting from several days of dry weather. When these classes of fuel become dry fires burn hotter, are harder to control, and require more mop-up work. But here, also, a means of appraising inflammability has been determined. It has been found that the number of days elapsed since the latest rain of 0.50 inches or more is a useful index of cumulative drying. Because of differences between mountain (hardwoods) and coastal plain (pinewoods) fuel types, this factor is of less importance in the coastal plain particularly in the winter and spring season.

<u>Wind</u>. Measurements of wind velocity are important, because (1) wind velocity is difficult to estimate, and (2) wind velocity is of first importance in affecting rate of spread if fuels are dry enough to burn. Measurements of velocity can be made with any one of a number of buzzer-type anemometers.

Because coastal plain fuels (principally dead grass) are finely divided and exposed to the air, wind velocity must be given more weight in the flatwoods than in mountain forests.

<u>Condition of Vegetation</u>. The state of the physiological activity of plants, varying with latitude, elevation, and aspect, is another factor which contributes to the degree of fire danger. For example, grasses, weeds, and shrubs tend to retard the rate of spread of fire as long as they are succulent and transpire large quantities of moisture; but when they are dry their effect on fire behavior is reversed. This difference in inflammability resulting from physiological condition is outstanding in the pine forests in the lower country where grass is a primary fuel. Transition periods, when vegetation is coming up in the spring or when it is curing in the fall, are intermediate in their effect on fire danger. In some sections of the East this transition is very gradual in the fall, in others it is very abrupt owing to sudden heavy autumn frosts.

<u>Season of the Year</u>. The intensity of solar radiation obviously

determines the drying-rate of forest fuels, and since it varies with the calendar the season of the year becomes an important fire danger factor. This is particularly true in mountainous or hilly country where the movement of the sun towards the zenith as spring and summer approach causes more rapid and complete drying on north slopes. In fall and winter north slopes often act as good fire breaks because sunlight reaches the ground for only a few hours each day or perhaps not at all. In the flat country such effects do not exist, of course, and season of the year is not as important as other variables.

Season of the year is also a direct measure of length of day. During summer months the days are long and with more hours of sunlight fuels tend towards low moisture levels for longer periods. In the summer, shade of a hardwood overstory somewhat reduces the effect of long days because dead ground fuels are not exposed to sunlight at all. Length of day is a factor during the leafless seasons, however. Long, cool, humid nights at this time of the year create more favorable conditions, of course, and the burning day is considerably shorter. This is particularly true at northern latitudes where the length of day may change seven or eight hours during the year. Even in the southernmost portion of the Appalachian region length of day changes four to five hours from winter to summer.

Thus, the four key factors to be measured in the danger rating system are (1) fuel moisture determined from wood sticks and number of days since 0.50 inches or more of rain, (2) wind, (3) condition of vegetation, and (4) season of year.

Systematic Measurement of the Key Factors

Fire danger is ordinarily determined from measurements taken several times a day at a network of stations[3] so located as to sample major variations in fire-weather caused by topography and other physical features. A typical fire danger station consists of a fuel moisture scale housed in a weighing shelter, a set of indicator sticks, an anemometer, and a rain gauge (see illustration on the following page).

Fire occurrence is also an important consideration in the location of stations; hence danger should be measured at points where fires normally occur with the greatest frequency.

Ordinarily, one station for every 150,000 acres of protected land in the mountains and one per 300,000 acres of land in level or rolling country is a suitable number with which to start. If this is insufficient, "holes" in the network will soon become evident and can be filled.

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[3] See pages 27 and 28 for complete description of selection of fire danger station locations.

Three daily measurements of fuel moisture, wind, and rain provide the data necessary to follow the development of critical conditions as well as to obtain an accurate average daily danger rating. Any towerman, guard, or C.C.C. enrollee can read the instruments and record the observations in about five minutes.[4]

Integration of Measurements

Current measurements of the key fire danger factors are integrated or woven together into numerical classes by means of two danger meters, one for the mountain region, the other for the coastal plain. These meters are simple cardboard "slide rules". The mountain type is illustrated on page 7.[5]

The factors integrated into these current danger classes by the mountain meter are: (1) fuel moisture as indicated by wood sticks and days since latest rain of 0.50 inches or more, (2) wind velocity,

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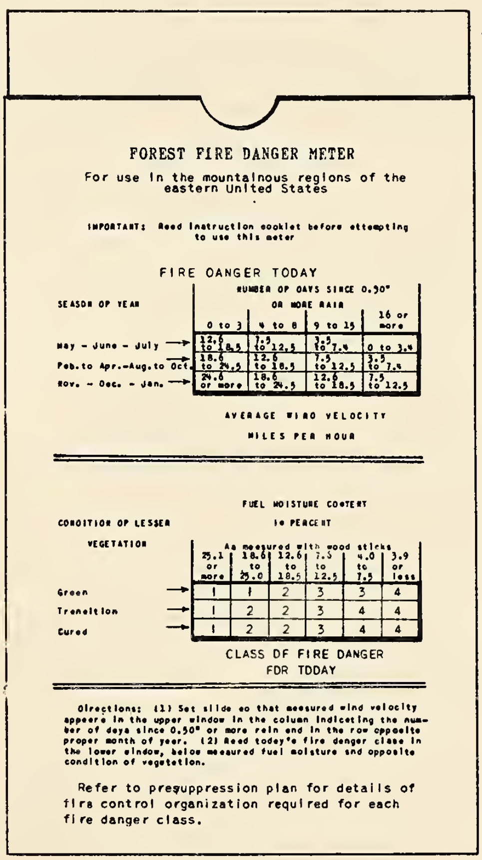
4/Pages 29 to 36 explain procedure in detail.

5/The Northeastern Forest Experiment Station, New Haven, Conn., supplied weather records for checking this danger meter.

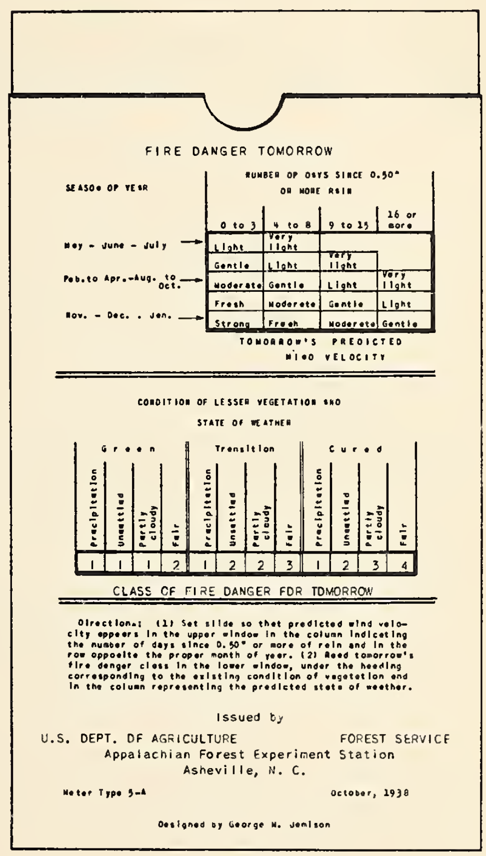
(3) condition of lesser vegetation, and (4) season of year. The "season of year" factor is not of sufficient importance to require consideration on the coastal plain meter, and because of regional variations in climate, latitude, elevation, and forest types, the other factors are given different weights on the two meters.

Predictions of fire danger class for not more than a 24-hour advance period are desirable because of the characteristic rapid and frequent fluctuations in danger that make it difficult for fire control men to estimate class of danger for the future. To overcome the inaccuracies associated with individual forecasts of danger, a system has been developed by which ratings can be predicted. Essentially, current ratings of fire danger are modified on the basis of the state of weather and wind forecast for "tomorrow".

Actual operation of the danger meters is extremely simple and merely involves setting of one movable slide. When this slide is set according to directions on the meter, the danger class can be read for each combination of conditions. On both types of meters the front is used for rating existing danger and the reverse side for prediction of danger for the following day.



FRONT

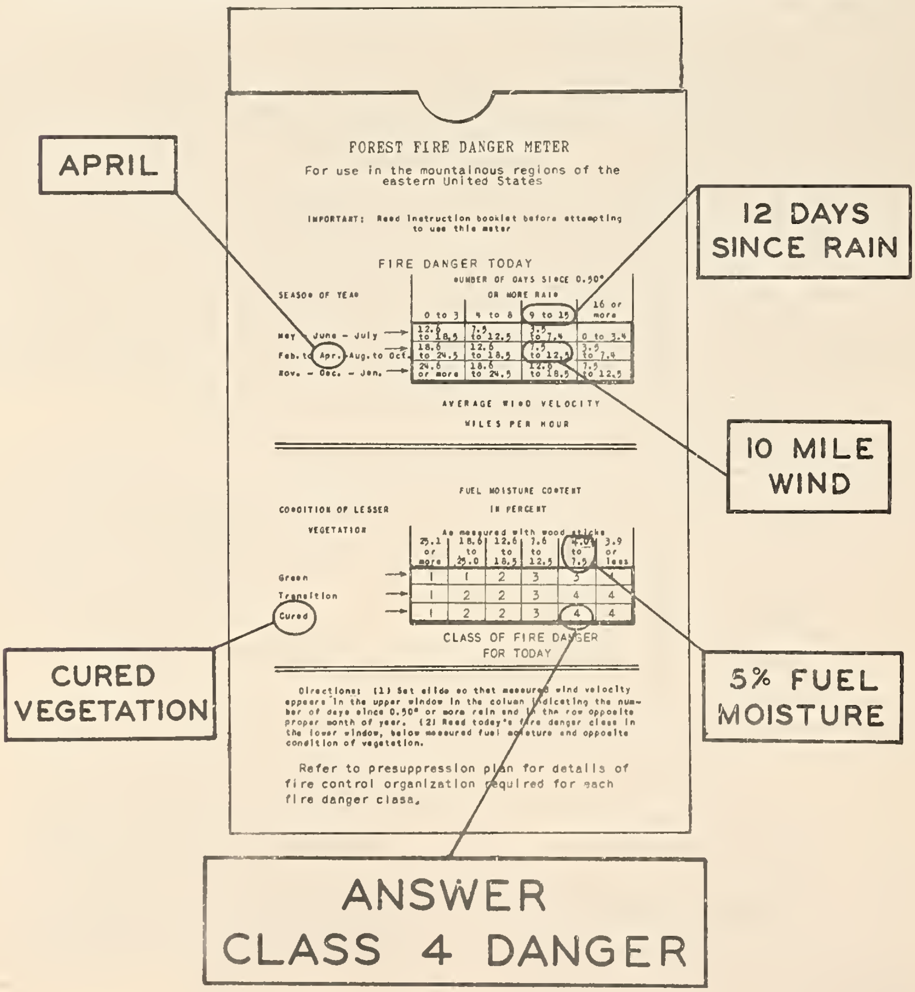


BACK

Danger is rated on a numerical scale of one to five, class one representing no danger and class five the very greatest that can be experienced. The corresponding classes of the mountain and coastal plain meters are directly comparable in this respect. Both meters express

HOW A DANGER METER WORKS

SUPPOSE IT IS APRIL 10, 12 DAYS SINCE IT HAS RAINED 0.50 INCHES OR MORE, WIND IS BLOWING 10 MILES PER HOUR, FUEL MOISTURE IS 5%, AND GRASS, WEEDS AND SHRUBS HAVE NOT YET BECOME GREEN.



relative degree of danger only. Actual rate of spread of fire is another matter and depends partially on factors not considered in the danger rating system, particularly kind of fuel, its volume and arrangement, and the topography of the region.

Relation Between Danger Measurement and Organization

Integration of fuel and weather measurements into danger classes is not an end in itself. The fire control organization necessary to insure adequate detection at all times and proper speeds and strengths of attack in all fuel types should be set up for each danger class.

The determination of the proper organization that should accompany each danger class has to be based on study of normal fire occurrence, fuel types, and values at stake, and must be modified when necessary on the basis of current visibility and abnormal fire occurrence. Such considerations tell where and how many facilities should be employed. Danger ratings tell when these facilities must be made available.

A brief description of the way each major consideration fits into the philosophy of fire control planning is needed to illustrate the function of fire danger measurement.

Objectives

It is not the purpose of this paper to discuss at length the various fire control objectives. However, objectives must be decided upon before planning can be undertaken, since they govern the choice of detection, travel time, and suppression standards - the primary controls of the type and strength of organization adopted.

Occurrence

The normal frequency of fires is a basic consideration in location of lookout towers, patrol routes and suppression crew stations. Areas where fires are concentrated should have the best coverage and fastest attack, other things being equal. The analysis of occurrence of fires by causes also indicates where prevention work is necessary.

In the East where 98 percent of fires are man-caused, abnormalities and sudden shifts in the activity of fire starting agencies cannot be anticipated or measured until after fires occur. Therefore, there is little possibility of bringing this temporary or changing aspect of risk into a danger rating system. About all that can be done is to vary scheduled organization when there is some local evidence, such as seasonal tobacco-bed burning, to indicate greater chance of fires starting. The following figures (obtained from analysis of 467 fires occurring in the southern Appalachians) indicate the probability of occurrence on days of different danger classes. Such data can be used to guide the planning of organization on the basis of occurrence.

Fire danger class	Probability of occurrence
1	1
2	2
3	8
4	23
5	56

Thus, the probability of a fire occurring is 56 times as great on a class 5 day as on a class 1 day.

Fuel Types

A classification of fuel types from the standpoint of rate of spread and resistance to control completes the picture of the fire control job to be handled by a given organization. Expected rate of spread indicates the length of fire line to be built, resistance to control indicates the difficulty of constructing the line for a given fuel type. Together, rate of spread and resistance to control measure required man-power, which, multiplied by normal occurrence, gives the total fire job. Such information is essential in the determination of every phase of man-power placement, location of communication and transportation facilities, and strength of attack.

Rate of spread and resistance to control data for each fuel type by danger classes would be very valuable but such information is not yet available. Instead, rates of spread for several hardwood types (Appalachian Mountain) and several pine types (coastal plain) constitute the data available at this time for the East. Some of these figures are given below:

Fire Danger	Rate of Spread in Chains Perimeter Per Hour	
Class	Hardwood fuel types (basis 455 fires)	Pine fuel types (basis 83 fires)
1	1	3
2	3	18
3	8	48
4	12	126
5	16	No data

Values

Values at stake are a requisite of organization planning although some agencies do not consider them. Theoretically, at least, the fastest action and the strongest attack should be provided on areas having the greatest value if all other things are the same.

For example, on a class 3 day, a stronger force should be available on a watershed producing a city's water supply than on a similar area with lower value.

Visibility

In eastern fire danger rating schemes visibility distance, although a factor that changes from day to day, is not included as a variable on the danger meter but rather is considered in organization plans. A smoky atmosphere does not directly affect fire behavior. Therefore, it seems more reasonable to vary the detection organization as visibility changes because if a certain detection time standard is maintained, strength of attack does not need to change with visibility distance.

To sum up, sound fire control planning, basic to every phase of fire control, first requires an inventory of occurrence, fuels, and values. To the relative classes into which the total range of danger is divided, required organization procedures, determined from this inventory, are assigned. The danger meter indicates the severity of burning conditions but "what to do about it", is a function of the organization plan. Organization plans for a typical national forest in the southern Appalachians are presented in graphic form on accompanying pages.

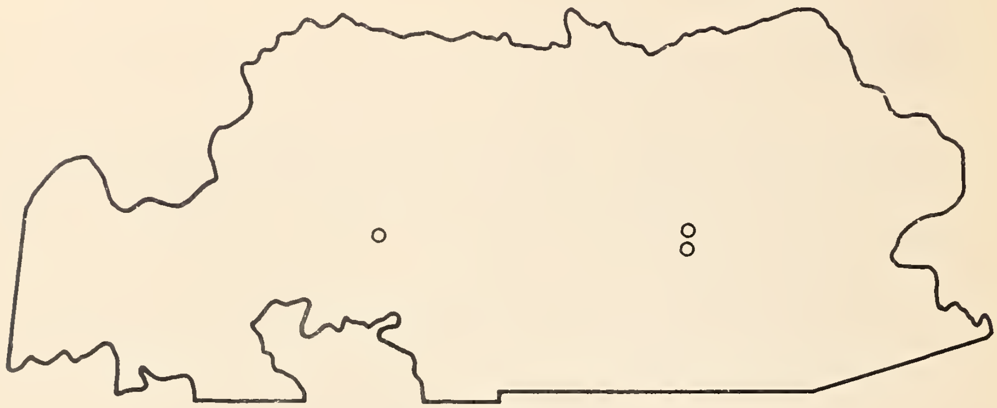
Specific Uses

Those who have used fire danger ratings have found that numerical classes, determined from measurements instead of guesses, have helped them handle their fire control jobs more effectively. The originators of the fire danger measuring system in the West probably had no idea at first of the extent to which danger ratings might be used. Even yet there is not complete understanding of how ratings may help in all phases of fire protection. A list of some of the uses of these ratings has been prepared and is discussed below.

Application in Fire Prevention

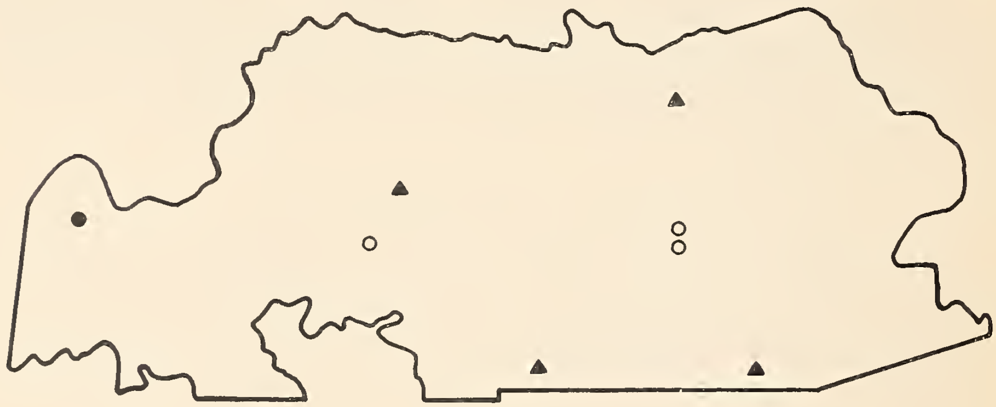
1. In some of the southern Appalachian fuel types the chance of a fire brand starting a fire is about 28 times as great on a class 5 day (most critical) as on a class 1 day (lowest danger). Thus, fire danger ratings can be used to indicate relative "ignitibility" of similar fuels. Presumably, there are just as many cigarettes and matches discarded, as many locomotive sparks scattered, and as many other fire starting agencies active (except debris burners and incendiaries) on days of high danger as on days of lesser danger.

NANTAHALA NATIONAL FOREST



CLASS 1

NO MEN ESPECIALLY DETAILED TO FIRE CONTROL. REGULAR FOREST ORGANIZATION ON NON-FIRE PROJECTS



CLASS 2

KEY LOOKOUT STATIONS MANNED

CLASS 3

ALL DETECTION STATIONS MANNED

FIRE ORGANIZATION PLAN

CLASS 4

ONE OR MORE SUPPRESSION CREWS IN OR NEAR CAMP, OTHERS PROVIDED WITH TELEPHONE COMMUNICATION. WARDENS NOTIFIED OF DANGER. PATROLS USED ONLY WHEN VISIBILITY IS LESS THAN 5 MILES.

CLASS 5

CREWS SPOTTED AT ESPECIALLY HAZARDOUS LOCATIONS. PLANS FOR FOLLOW-UP REPLACEMENT PUT INTO EFFECT. PATROLS USED ONLY WHEN VISIBILITY IS LESS THAN 5 MILES

LEGEND

O	RANGER OR SUPERVISOR	■	CREW
▲	LOOKOUT STATION	～	MOTOR PATROL
●	GUARD	⁓ (dashed)	FOOT PATROL
×	WARDEN		

In any test of the effectiveness of a fire prevention campaign the danger existing during the period must be considered, otherwise a reduction in the number of man-caused fires due to favorable weather conditions might be mistaken for good prevention technique. Conditions that influence the ease of ignition can be considered in studies of the efficiency of prevention work if fire danger ratings are available.

2. Danger ratings can be used to show the need for better legislation to control the use of fire. If the majority of forest fires caused by debris-burning operations originate on days of high danger, it is very evident that restrictions (other than calendar date which is almost meaningless) be placed on such activities. For example, in a portion of one eastern state 76 percent of fires that escaped from debris-burners over a six-year period did so on class 4 and 5 days, the two highest danger classes.

3. Danger ratings serve as useful guides in the current regulation of prevention measures such as closure or reopening of woods to entry, restrictions on smoking, on debris-burning, and on campfires. The use of comparable danger rating schemes can eliminate annoying variations in regulation by adjacent states or different agencies within a state. Lack of uniformity resulting from variations in judgment confuses the public and destroys its confidence in forest fire prevention agencies. In the far East and South, where recreation and other forms of public use are especially important, national forests, national parks, Indian reservations, state departments and many private agencies individually practice fire prevention to some extent. With so many different organizations functioning, reasonable uniformity in regulating the use of fire is essential.

4. Numerical danger ratings are readily understood by the average layman and can therefore be advantageously used to educate hunters, campers, fishermen, and tourists. They are willing to be extra careful on bad days if they know that the definition of a "bad" fire day is based on something more than a mere guess. Ratings have much public appeal when presented in showy form. Fire danger display boards, colored flags similar to storm warnings, and a large variety of showy displays have been worked out on the basis of measured fire danger classes to educate and interest the general public and users of the forests.

Use of Fire Danger Ratings in Presuppression

1. Fire danger records for several years can be used to determine whether or not additional expenditures for fire control activities are justifiable. On the basis of such records the accomplishment to be expected for different expenditures under normal conditions can be

determined. An accumulation of danger ratings for different fire control units will show legislators and those who administer fire funds the comparative financial needs of the several units.

2. Fire danger ratings can be used in building up or cutting down a presuppression organization as weather and other temporary aspects of fire danger change. When a man in charge of fire control hires guards and lookout men by the day, employing them only when it is "dry", and depending on his own or someone else's judgment, sometimes men are on the job when they are not needed, and at other times they are not available when they should be. With an organization planned to function on the basis of fire danger ratings, however, lookout men, patrolmen, guards, and crews go on fire duty when they are needed. Likewise during periods of low danger these men can be safely used on nonfire projects. If fire danger actually differs between ranger or warden districts, then the operation of lookout towers varies correspondingly and the district dry enough to have fires has its lookout points manned.

3. A danger rating scheme indicates unseasonable periods of fire-weather and prevents fire control organizations from getting caught unprepared in off-season letdowns. In some sections of the country long fire seasons are not as common as short periods of high fire danger occurring throughout the year. Some of the most disastrous fires have resulted from the inability of fire men to recognize the development of a dangerous period in time to be prepared for it.

4. Danger ratings assist a new man or even an old-timer in new country to become familiar with his fire job without having to learn by costly experience. He may analyze past records and see what actual fires have done under specific measured conditions. He can understand and interpret such records, being sure that they are not influenced by someone's personal opinions, for danger ratings are just as specific as the measurement of distance in feet or time in minutes.

5. Comparability of man-power needs between two or more fire control units can be determined most logically only if ratings of <u>normal</u> danger are available. Fire danger measurement provides part of the information essential in judging whether districts or forests are comparably manned. Although other considerations, such as normal occurrence, fuel type, and values, are extremely important in such a determination, they are not complete without the knowledge of normal fire danger compiled to show the seriousness and duration of conditions confronting each organization.

6. Fire danger ratings, which are numerical classes and not indefinite terms like "good", "bad", or "very bad", permit exact comparisons of the severity of conditions in two or more districts,

forests, states, or regions. Thus the accomplishments of different administrative units can be balanced against the seriousness of fuel and weather conditions under which each organization worked.

For example, scarcity of fires and smallness of area burned have often been misconstrued as evidence of good fire prevention and suppression, whereas the real reason was a very easy fire season. Conversely, a good fire record might be taken to indicate an easy fire problem, whereas the accomplishment was really the result of exceptionally fine work by the fire control organization in spite of critical weather. Obviously the efficiency of a fire control organization should not be judged only on the basis of fires and acres burned.

7. Fire danger ratings make possible exact comparisons of seriousness of fire seasons by <u>years</u> for any unit. It is quite useful to be able to compare a current year's accomplishments in fire control with those of past years. Also, in planning the financial aspects of fire control it is desirable to know the frequency of critical and easy years. Danger ratings form a valid base for such a classification.

8. Standardization of fire danger terminology through use of numerical danger classes is especially valuable in showing the need for cooperative fire funds and in justifying their use. Where mutual interest in a fire control job makes it desirable for two organizations to join their efforts or pool their facilities it is just good business to be able to determine what the money of each division is "buying". Danger measurement helps in doing this.

Fire Danger Ratings Assist Suppression

Not only does the pre-fire distribution of man-power on the basis of measured fire danger insure faster action when a fire does start, but the fire danger ratings can also be used as an aid in the actual suppression of fires by dispatchers and fire bosses who have a knowledge of fire behavior by danger classes. Measurements of existing danger serve as guides for dispatchers in sending men to a fire in numbers commensurate with the class of danger prevailing. Fire bosses are likewise guided in reducing the man-power on a fire as danger decreases.

Danger Ratings Applied to Damage Appraisal

Ratings of fire danger can be used to indicate the intensity of a fire in a given fuel type. This information, in turn, is essential to the proper rating of fire damage, especially in hardwood and some southern pine types. Most fire control organizations do not now have the personnel available to make a detailed survey of each burned

area and must rely on generalized tables to ascertain damage after a fire. The most practical way to approximate damage in a known stand of timber is to correlate it with fire intensity as indicated by danger measurements. In some types mortality may cumulate for five or more years after a fire, the damage varying, of course, with fire intensity. In some instances it is desirable to initiate legal proceedings to collect fire damages. These cannot wait for a fifth-year examination to be made to determine total mortality. A danger rating, obtained during the fire, often serves as an index of expected losses that hinge on fire intensity.

Danger Ratings as Guides in the Silvicultural Use of Fire and in Hazard Reduction

If the use of fire should be found advisable in silvicultural practice and in hazard reduction, fire danger ratings are helpful as indicators of times when such use is safe. A good understanding of the severity of fire expected for different classes of danger takes much of the guess-work out of burning planned to improve game food supplies, stand composition, seedbeds, and certain other conditions involved in the management of forest resources. Danger ratings have a place, too, in controlled burning for protection in that they help determine when maximum fuel reduction with minimum damage or risk can be obtained. Hundreds of miles of strip between parallel plowed fire lines is burned every year in the south where firebreaks are maintained. More efficiency is obtained from the burning crews if their activities can be guided by measured danger. The best job is obtained with the least undue risk.

Conclusion

Because of its simplicity and utility fire danger measurement should play an important part in the successful operation of any fire control organization. Danger rating systems suitable for use in hardwood types and pine forests of eastern United States have been developed. While there is no precise way to evaluate the dollars and cents return from the use of danger measurements it is significant that not a single fire control organization that has given the method a thorough test has ever concluded it has not paid its way.

INSTRUMENTS AND WEIGHING SHELTER WITH PLANS FOR MOUNTING AND ERECTING

A fuel moisture scale and set of fuel moisture indicator sticks, rain gauge, anemometer, and weighing shelter comprise the entire list of equipment needed at a fire danger station. The following information

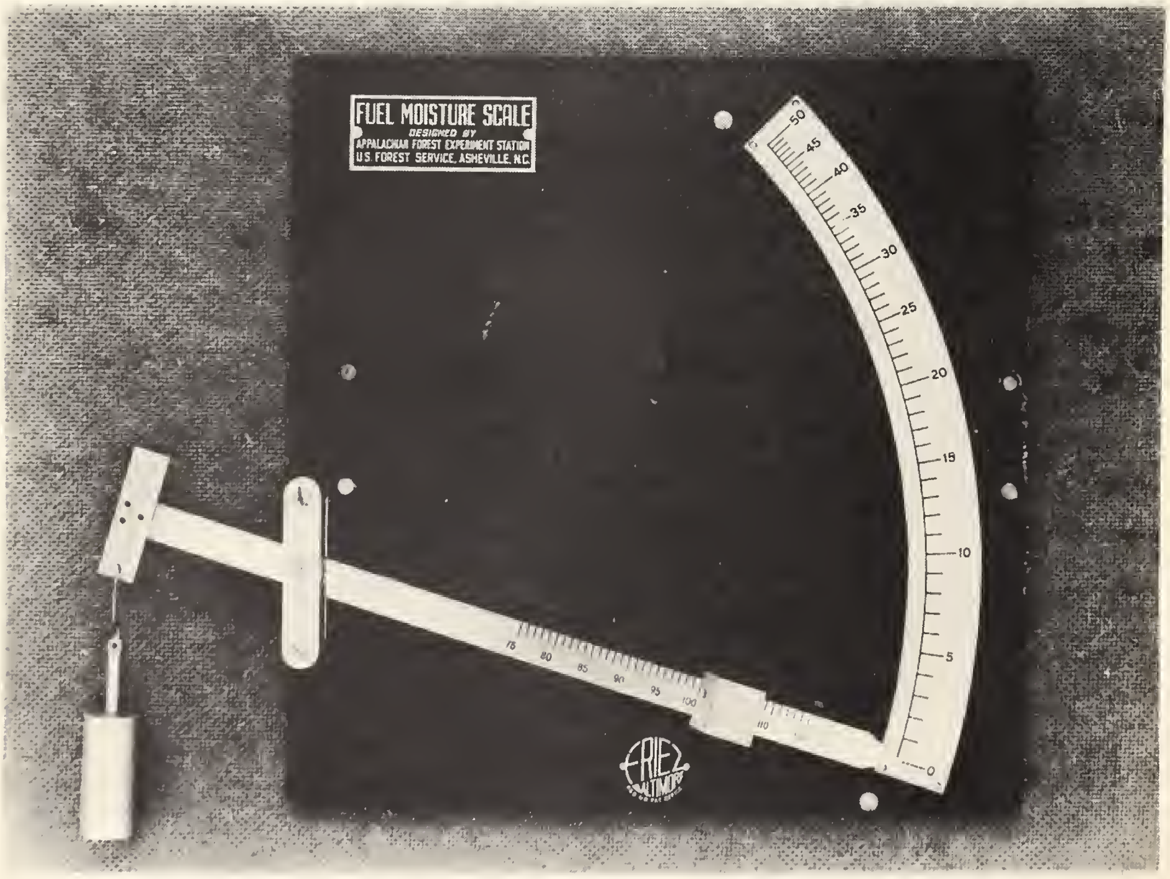
will be helpful in planning for such a station.

Essential Instruments

Fuel Moisture Scale

The fuel moisture scale, developed by Byram of the Appalachian Forest Experiment Station, is used to determine the moisture content of fuel moisture indicator sticks. The instrument consists of a pivoted balance arm or beam mounted on a lacquered 10-by-10-inch aluminum back. A sliding weight or counterbalance on the beam is used to adjust the scale for sets of sticks of different oven-dry weights from 75 to 115 grams.

The balance arm of the instrument has a small hook on the left end to which a set of wood sticks is attached when a reading is to be obtained. The other end points to the average moisture content of the sticks, shown on a curved scale graduated from zero to 50 percent.



The balance arm pivots on a nickel-silver pin. All other parts except the back are of solid brass. nickel plated. A standard 100-gram test weight accompanies each instrument and may be used as a ready method of leveling the device to obtain the zero setting as shown in the accompanying illustration. Each scale is packed in a wooden box suitable for shipping. Detailed specifications may be obtained from the Appalachian Forest Experiment Station, Asheville, N. C.

Tests show that in low ranges the instrument will indicate true moistures within ±0.1 percent, while at 50 percent the error that may be expected is ±0.5 percent.

Instruments may be obtained from the following manufacturers at a cost of $8.00 to $10.00 each:

Julien P. Friez and Sons
Division of Bendix Aviation Corporation
Baltimore, Maryland

Walter F. Backus
3713 S.E. Division Street
Portland, Oregon

A satisfactory mounting for the scale in a weighing shelter is described on page 27.

Fuel Moisture Indicator Sticks

The Appalachian type of fuel moisture indicator sticks, made from basswood Venetian blind stock, can be obtained free of charge from the Appalachian Forest Experiment Station, Asheville, North Carolina. A calibration card, enclosed with each set of sticks, shows the proper settings of the sliding adjustment on the balance arm.

When sticks are lost, broken, or chipped a new set should be requested at once. Sets in use more than five months should be replaced. A set of sticks in typical exposure is shown on page 20.

Rain Gauges

A rain gauge consists of a sharp-edged, funnel-shaped receiver that concentrates precipitation into a small metal measuring tube housed in a larger metal container. The "catch" of rain is measured with a small graduated ruler or measuring stick. The area of the receiver to the tube is 10 to 1. Therefore, an inch of water in the tube indicates but one-tenth inch of rain.

The standard rain and snow gauge, Weather Bureau pattern, may

be obtained from Julien P. Friez and Sons, Division of Bendix Aviation Corporation, Baltimore, Maryland, at a unit cost of about $14.00. The Taylor Instrument Companies, Rochester, New York, sell the same type of gauge for $17.00. United States Government agencies may obtain this pattern of gauge at a contract price of $7.40 from W. S. Jenks and Son, 723 Seventh Street, N.W., Washington, D. C. In general, the Weather Bureau pattern is the best gauge available and is about 30 inches high and 8 inches in diameter.

Most danger stations use the Forest Service rain gauge. This is a much cheaper instrument than the standard type but just as satisfactory. It is made of galvanized iron and is about twelve inches high and slightly less than eight inches in diameter. In other respects it resembles the larger gauge. Comparative tests conducted by Gisborne in northern Idaho and by the Appalachian Station indicate that the Forest Service pattern is satisfactory. A sample comparison of Standard and Forest Service gauges conducted at the Bent Creek Experimental Forest in western North Carolina follows:

Precipitation Readings

Date of Rain 1937	F. S. Gauge Inches	Standard Gauge Inches
June 7	0.10	0.10
8	0.50	0.49
9	0.10	0.10
15	0.07	0.07
16	2.03	2.00
17	1.17	1.19
18	0.76	0.75
21	0.06	0.06
29	0.11	0.10
30	0.20	0.20
July 4	0.56	0.56
5	0.10	0.10
16	0.11	0.12
19	0.49	0.49
20	0.20	0.20
25	0.06	0.05
26	0.99	1.00
29	0.68	0.66
30	0.16	0.16
Total	8.45	8.40
Average	0.44	0.44

Forest Service rain gauges can be obtained at a cost of $1.35 each from F. A. Anderson Manufacturing Company, 224 N. W. Glison Street, Portland, Oregon. When measuring sticks are broken, replacements may be obtained from the Davis White Company, 315 West Court Street, Milwaukee, Wisconsin, at a cost of about 20 cents each.

Rain Gauge Support. Rain gauges should be securely supported so that the funnel top is level and about waist-high. A Forest Service gauge will fit inside a square box formed by nailing together four 1-by-10-inch pine boards. This box, when fastened to the top of a post, makes a convenient and substantial support for the gauge.

Anemometers

There are a variety of low-cost cup anemometers satisfactory for use at fire danger stations. These are all the so-called "buzzer" type that indicate current velocity by transmitting signals or buzzes for each 1/60th mile of wind passing the instrument.

Some types are more accurate than others, especially at low velocities, but all can be recommended for danger measurement. The Stewart and Chisholm anemometers in the following list use correction charts to convert indicated to true velocity. Instruments may be obtained from the following manufacturers; prices are approximate and are for single instruments:

Dozier Manufacturing Company----------------$10.00
4223 Grove Street
Oakland, California

M. C. Stewart Company-----------------------$ 6.00
432-A Massachusetts Avenue
Arlington, Massachusetts

A. E. Chisholm------------------------------$ 9.00
2640 E. Burnside
Portland, Oregon

Julien P. Friez and Sons--------------------$18.00
Division of Bendix Aviation Corporation
Baltimore, Maryland

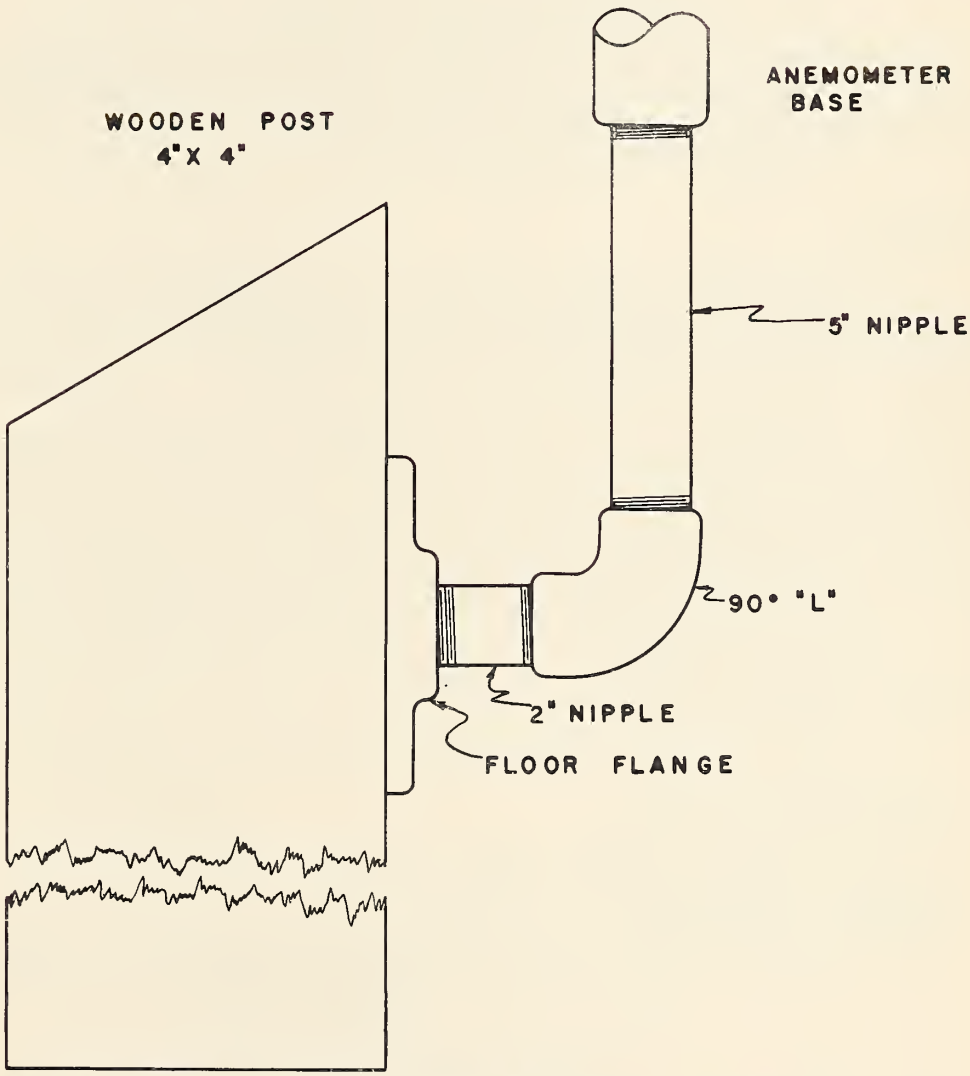
Mountings for Anemometers. Of the above instruments, only that made by Chisholm comes equipped with a mounting device. The Stewart and Dozier types will screw on a ½-inch standard pipe fitting. A ½-inch pipe can be ground down to fit the Friez instrument, the base of which has a smooth hole, tapering slightly from three-quarters of an inch in diameter. A brass, milled, mounting for the Friez anemometer can be purchased for about $4.50.

A suitable iron pipe mounting for the Stewart and Dozier anemometers is shown on the following page. All wire, batteries, buzzers, and switches necessary to complete the signal circuit can be purchased at any hardware store. A single 1½-volt dry cell battery will supply the necessary current unless the circuit is long. A small electric buzzer or flasher bulb provides the best signal and a push-button switch is recommended.

While the 1/60th-mile transmitters are satisfactory for fire danger measurement there is some advantage in having cumulated wind movement, for a more reliable average can then be obtained. The Dozier Manufacturing Company makes a watch-like wind mileage recorder and velocity meter which shows total wind movement when attached to any buzzer-type anemometer. These attachments sell for $15.00 each.

Standard anemometers of high quality, with dials from which total

ANEMOMETER MOUNTING



ALL FITTINGS GALVANIZED IRON, STANDARD THREAD.
STEWART AND DOZIER REQUIRE 1/2" PIPE FITTINGS.
FRIEZ ANEMOMETER CAN BE FITTED TO THE 5" NIPPLE, GROUND WITH SLIGHT TAPER, TO FIT THE SMOOTH HOLE IN BASE OF INSTRUMENT.

wind movement to the nearest tenth of a mile can be read, may be purchased from the Julien P. Friez Company for prices starting at $80.00. Instruments can also be obtained with the additional 1/60th-mile transmitting feature.

The standard height of anemometer exposure for the Appalachian danger rating systems is eight feet. A suggested position for mounting the instrument on top of the shelter post is shown in the illustration on page 6.

Supplementary Instruments

The instruments listed are the only ones required at standard fire danger stations but, because some individuals are interested in observing changes in temperature and humidity as a supplement to danger measurements, information on them is included.

Psychrometers

All psychrometers consist of a wet and a dry thermometer bulb which must be ventilated as a reading is taken. Tables convert these readings to relative humidities. Three general types suitable for use at danger stations are available, the sling, fan, and hand-aspirated psychrometers.

Sling psychrometers are the most difficult to use and the most easily broken but they have the advantage of being portable. Fan psychrometers are not so easily carried but are more accurate than the sling in the hands of the average observer and are less liable to breakage. The same holds true of the hand-aspirated instrument but this has an added advantage of being small and easily carried around, but rapid deterioration of rubber parts makes maintenance costs on this instrument excessive. Of all types, probably the fan psychrometer is the best for use at the average station.

Approximate prices for the various instruments obtained from different manufacturers follow:

Julien P. Friez and Sons
Division of Bendix Aviation Corporation
Baltimore, Maryland

Hand-aspirated----------	$15.00
Swivel sling, 12"-------	12.00
Pocket sling, 7"--------	7.00

Taylor Instrument Companies
Rochester, New York

Standard sling, 12"-----	$15.00
Pocket sling, 7"--------	8.00

G. M. Manufacturing Company
P. O. Box 151, Madison Square Station
New York, New York

Fan type ------------------------- $10.00

Walter F. Backus
3713 S. E. Division Street
Portland, Oregon

Fan type ------------------------- $ 7.00

Psychrometric tables, necessary with any of the above instruments, are published as Weather Bureau Bulletin 235 and may be obtained at a cost of ten cents from the Supt. of Documents, Washington, D. C. Leaflets taken from this bulletin are available from the Appalachian Forest Experiment Station, Asheville, N. C., without cost. When such leaflets are requested, elevation of station should be specified.

Thermometers

A variety of thermometers can be obtained from almost any instrument company but the standard maximum and minimum, Weather Bureau pattern, are stocked by the following companies:

Taylor Instrument Companies
Rochester, New York

Henry J. Green
1191 Bedford Avenue
Brooklyn, New York

Maximum and minimum thermometers cost about $3.50 each. A metal thermometer support, used for holding them and setting the maximum thermometer costs $4.00 at the Taylor Companies.

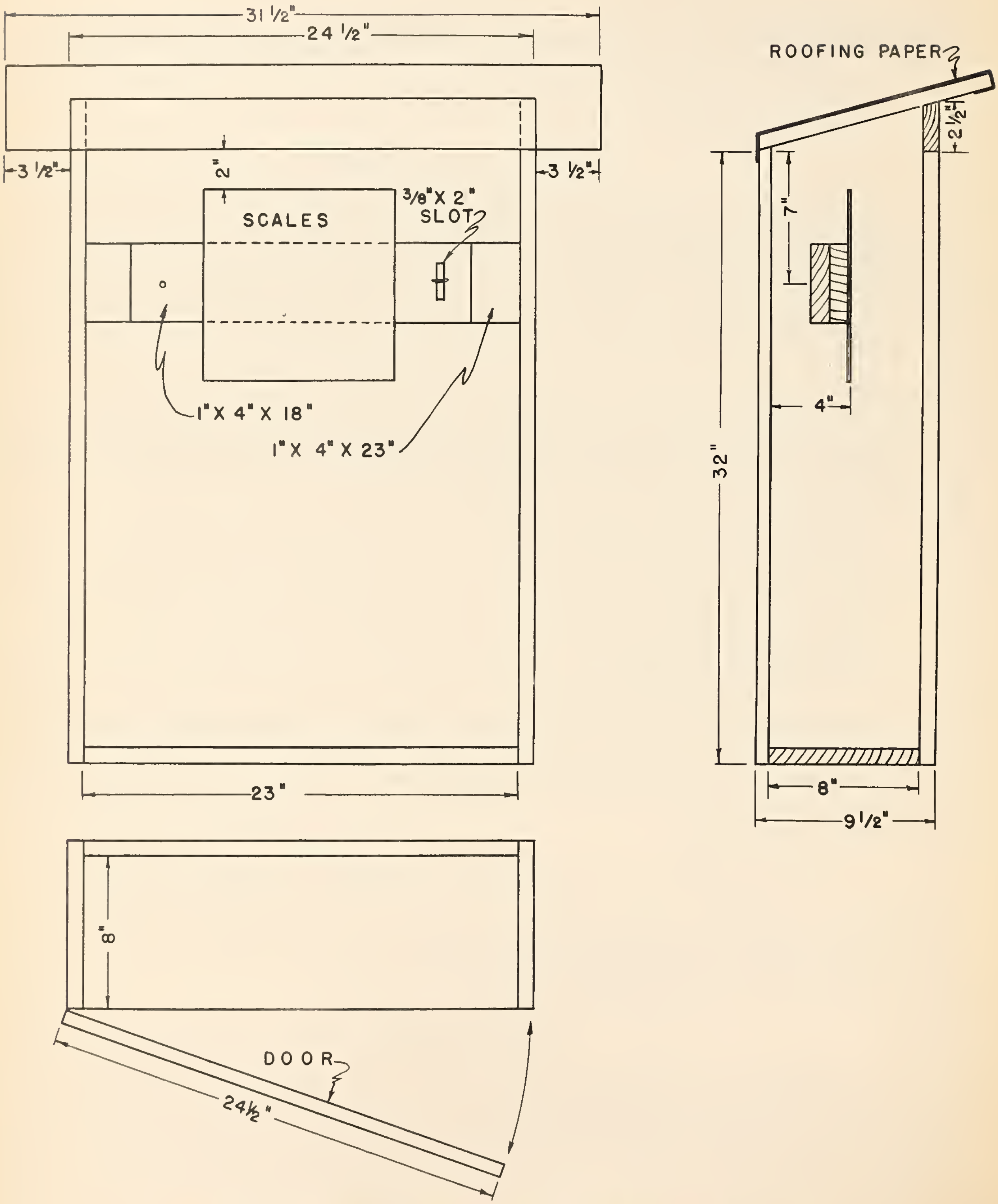
Recording Instruments

Instruments that record barometric pressure, temperature, and humidity or a combination of the two latter elements may be obtained from any of the large instrument companies. The cost of those that trace an automatic record on a weekly chart starts at about $75.00. Their use is not necessary at fire danger stations.

Weighing Shelter

A weighing shelter is necessary at a fire danger station to protect the fuel moisture scales from the weather and to provide shelter from the wind during the actual process of moisture determination. It is also convenient to have in one shelter the wind circuit battery, switch, and buzzer. Other equipment such as test weight for scales,

DIMENSIONS OF WEIGHING SHELTER



ONE 4"X 4"X 10' POST RECOMMENDED FOR SHELTER SUPPORT

rain measuring stick, and wind correction chart may also be kept there.

The weighing shelter should be a weather-proof box of the dimensions shown in the drawing on the opposite page. It should be mounted substantially on post or tree, preferably the former, which will be free from vibrations and sway caused by wind. A full-sized hinged door on the front of the shelter is most convenient and gives the observer plenty of room in which to work.

Mounting for Fuel Moisture Scale

The fuel moisture scale must be mounted substantially in the shelter so that the top edge of the instrument is two inches from the roof of the box. This will give plenty of room for the wood sticks to hang from the scale without striking the bottom of the box.

An easy way of mounting the device, described below, permits leveling it quickly and accurately. First, screw the scale firmly to a piece of wood 1-by-4-by-18-inches long. Four holes are provided in the scale back for this purpose. Bore a $\frac{1}{4}$-inch hole near one end and cut a 3/8" x 2" slot across the width of the board near the other end. Then fasten the board with scale attached to a board 1" x 4" x 23" long by means of $\frac{1}{4}$" x $2\frac{1}{2}$" bolts with wing nuts and washers. The 23-inch cross piece is fastened to the sides of the box so that the scale is about 4 inches from the back of the shelter. The cross piece holding the scale should be approximately level. The slot will permit precise leveling of the scale before the wing nuts are tightened. It may be leveled again if the ground settles and tips the shelter slightly from the vertical.

THE OPERATION OF THE FIRE DANGER MEASURING SYSTEM

Selection of Fire Danger Stations

Number

The number of stations required to sample adequately the major differences in fuel moisture and weather conditions depends primarily on topography; that is, on elevation and aspect. In the mountains of the East about one station per 150,000 acres or one per 300,000 acres in level or rolling country is enough to begin with. "Holes" in the network will show up if the degree of sampling is insufficient.

An additional consideration in deciding the number of stations needed is local fire occurrence. Where concentrations of man-caused fires usually exist, danger should be measured at the expense of other

areas where fires seldom occur, if a sacrifice is necessary. In some areas fires are almost entirely confined to valleys; consequently there is little need for measuring danger on adjacent high mountains. The danger station needs, therefore, must be determined separately for each section of the country.

Site

The exact spot for setting up a fire danger station should be selected with extreme care because actually the fuel moisture and wind will be typical of only the immediate surroundings. If the site is typical of the problem areas, however, the danger ratings obtained can be used with certainty that they represent conditions of major importance.

All stations following the previously described systems of danger rating should be located under natural forest conditions if satisfactory results are to be obtained. The surrounding vegetation and ground cover should be as nearly typical of the general area as can be found, especially in regard to species, density, and size. In the mountains a level spot or gentle south-facing slope is standard exposure. Sometimes, at a desired station a southeast or southwest slope must serve because of the absence of a more desirable aspect. In general, northerly and easterly exposures should be avoided.

Instrument Exposure

In hardwood stands the exact spot to place the wood sticks is easily determined after a representative site has been chosen, because the natural fuels are essentially fully exposed to the sun during the leafless season and completely shaded during the summer. Comparability between danger stations in a hardwood region, quite an important consideration, is easily obtained by placing the sticks where they will get such sun-shade conditions.

In coniferous stands the sticks should be located so as to get partial sunlight and shade throughout the day, in a proportion approximate to that received by natural litter. If the stand is typical in density of the type to be sampled, then a suitable stick location can be chosen by study of probable sun and shade patterns at each of several possible spots. On some areas, such as cut-over land or blowdown, the sticks must be exposed to full sunlight to be typical of natural fuel.

Anemometers should be supported so that the cups are at the standard 8-foot level. This exact height above ground is not imperative and a leeway of not more than a foot in either direction is permissible.

Instruments should not be placed so as to be sheltered by structures or other barriers to wind movement except that they should be exposed under typical conditions of forest or field. Anemometers should not be nearer than 10 feet to trees 10 inches or larger in diameter.

The rain gauge should be in an opening in the forest or a nearby clearing where a 45 degree angle from the top of the gauge clears the nearest obstacle. Sometimes such an exposure is not possible but it should be selected when available. Next best is to place the gauge directly under the center of the largest crown opening.

General Arrangement of Danger Station Equipment

The arrangement of danger station equipment should be similar to that shown on page 6. The fuel moisture indicator sticks are supported on wire brackets 8 inches above the ground in such position as not to be shaded by the shelter. A distance of at least six feet is satisfactory. The rain gauge may be placed nearby if a spot that meets requirements can be found. Ordinarily the rain gauge will have to be placed in an opening in the vicinity of the main danger station.

It is highly advisable to construct a wire fence around the instrument exposure. This not only adds to its appearance but reduces the chances of stick breakage by domestic stock or wild game and meddling by passers-by. Ordinarily the equipment can be enclosed in a fence twelve feet square or less. Sometimes a smaller wire fence around only the wood sticks serves the purpose. It should not be made of heavy rails that will shelter the sticks from sun, wind, and rain.

Instructions for Observers at Fire Danger Stations

The utility of fire danger ratings depends, of course, upon the reliability of the records that go into the ratings. Naturally, accuracy is of first importance in fire danger measurement. Fire danger station observers should realize that their accuracy and carefulness, above all else, is absolutely essential if the most is to be obtained from a system of danger measurement. Each observer should understand that the errors he makes carry right on through to presuppression and suppression action. He can be responsible for a fire getting away by his carelessness in handling and reading instruments.

Care of Instruments

The first step in obtaining reliable fire danger records is to be sure that instruments are exposed properly and thereafter are properly cared for. Suggestions for choosing the best exposure were

discussed above and this job will usually be taken care of by a forest officer. It will be the observer's responsibility, however, to take care of the instruments.

Fuel Moisture Indicator Sticks. Always be sure that the three sticks which constitute a set are kept on the two wire supports furnished with them so that they are flat side up, approximately horizontal, eight inches above the ground, and with the numbered side up and to the north as shown in the illustration on page 20. They should always be returned to this position immediately after each weighing. The many sets of wood sticks in use will not weather uniformly if one set is exposed one way and a second set in another manner. If the spot where the sticks are placed is exposed to high winds, it may be necessary to secure them to the wire supports to prevent them from being blown off. This may be done by weighting both ends of a string about 18 inches long and hanging this over the sticks or by using rubber bands to fasten them to their supports. Some observers have used a piece of heavy galvanized wire, hinged to one support so that it rests across the sticks and can be swung out of the way when a reading is to be taken.

The fuel moisture indicator sticks will give a reliable indication of the changes in fuel moisture content if they are handled carefully and the following points observed:

1. Never handle the sticks with sweaty, dirty or greasy hands. Excessive handling clogs the pores of the wood and it will not respond readily to atmospheric changes.

2. Handle the sticks carefully to avoid splitting, chipping, or marring.

3. When dust or dirt of any kind gets on the sticks, brush it off lightly with a clean, dry cloth or soft brush.

4. Notify the ranger or other responsible forest officer if anything happens to the set of sticks so that replacements may be made.

Fuel Moisture Scale. This instrument requires no special care except that it be handled as any delicate instrument should be. Do not oil the pivot. This is made from hard nickel silver and requires no lubricant.

Anemometer. The anemometer should be oiled once a month with a high grade of light instrument lubricant. While an animal oil such as porpoise or whale oil is the very best, good typewriter oil or 3-

in-1 is satisfactory. The buzzer-type anemometers should be oiled at the top and bottom of the spindle. When the cups are removed. a drop or two of oil may be applied to the top bearing. The face plate must be removed to reach the bottom bearing on which the spindle rests. Do not use an excessive amount of oil.

Anemometers should be taken down and carefully cleaned once a year. Observers should not take these instruments apart for cleaning unless they have been specifically instructed to do so by their superior officer.6/

The observer should be sure that the spindle of the instrument is plumb at all times. Otherwise, uneven wearing will result, readings will be in error, and the instrument will have to be replaced.

Rain Gauge. The top of the rain gauge should be kept level. The funnel must be handled carefully lest it become bent. Check this occasionally to see if the funnel is round; that is, not bent out of shape. All debris, such as leaves, needles, and insects should be cleaned out of the gauge regularly.

Reading of Instruments

Moisture Content Determination. Before stick moisture can be determined the fuel moisture scale must be checked to see that it is level or that its "zero setting" is correct. To do this, first set the sliding adjustment on the balance arm at 100 and hang the 100-gram test weight on the hook at the left end of the beam. Tap the pivot with the finger to settle the pointer to the correct mark. It may lag a little owing to a slight amount of friction at the pivot point. If the pointer does not read zero, loosen the wing nuts and move the slotted scale support until zero is indicated. After the wing nuts have been tightened check the zero point again. The scale should thus be checked and leveled once each week.

After the scale has been leveled the sliding adjustment is returned to a position that indicates the oven-dry weight of the set of sticks. The correct weight is shown on a card that accompanies each set. Because wood sticks weather and lose weight, a successively lower setting of the sliding adjustment is required every one-half month. The card referred to is reproduced on page 32.

6/See "Instructions for the care and use of airways anemometers", U. S. Weather Bureau, Asheville, N. C., for complete details of cleaning and assembling the Friez 1/60th mile indicating anemometer.

IMPORTANT

Set the slide on the balance arm of your fuel moisture scale as follows for wood sticks No. 270.

When first exposed.	________	(date)	104.2	grams.
at 2 weeks.	________	(date)	103.6	grams.
at 1 month,	________	(date)	103.0	grams.
at $1\frac{1}{2}$ months	________	(date)	102.3	grams.
at 2 months,	________	(date)	101.8	grams.
at $2\frac{1}{2}$ months,	________	(date)	101.3	grams.
at 3 months,	________	(date)	100.9	grams.
at 4 months,	________	(date)	100.0	grams.

POST THIS CARD IN SHELTER BESIDE SCALE

The wood stick serial number and the "grams" column of weights are filled in before the sticks are mailed. The observer must fill in the "date" column as indicated, beginning with the date when the sticks are first exposed. Notice that the card should be posted beside the scales in the weighing shelter.

When the sliding adjustment has been set correctly, the three wood sticks are hung together on the scale hook by means of the small wire loop fastened to each stick. Always tap the pivot before reading the scale. This is important and its omission has caused frequent errors in the past. Neither should the scale be read until the sticks have stopped swinging. The pointer indicates the average moisture content of the three sticks. This should be read to the nearest tenth of one percent and recorded on the form for that purpose.

Wind Measurement. Wind velocity may be determined at the stations equipped with a 1/60th mile transmitter or buzzer-type anemometer by counting the number of signals during a one-minute period. A two- or three-minute count is recommended, however, because it is much more accurate, especially on gusty days.

To take a reading, close the switch in the anemometer circuit and wait for a buzz or signal. Begin timing with a watch immediately after the buzz stops but do not count that signal. Begin counting at the next buzz and tally the total during a two- or three-minute period. For Friez or Dozier anemometers, wind velocity is then obtained by dividing the total by the number of minutes. For example, 10 buzzes in two minutes equals 5 miles per hour; 12 buzzes in three minutes equals 4 miles per hour. Correction charts, furnished by the manufacturers, that convert buzzes per minute to miles per hour must be used with the

Chisholm and Stewart anemometers.

An average of two separate readings is always desirable on days when the wind is unsteady and variable.

If a station is equipped with the more expensive Weather Bureau type anemometer with a dial, average velocity is obtained by subtracting one dial reading from a second, later one. To get miles per hour, this difference, which represents the total wind movement for the period, must then be divided by the number of hours between the two readings. For example, at 1 p.m. a reading of 621.5 was observed and at 5 p.m., 640.7. The difference is 19.2 miles, which, divided by 4 hours equals 4.8 miles per hour average velocity.

Precipitation. Rain is measured with a graduated ruler or measuring stick by inserting the stick slowly and carefully (to avoid splashing) into the small measuring tube of the rain gauge which holds the water, after the funnel top has been removed. The depth of the water is then read by withdrawing the stick and noting the position of the water line with respect to the nearest graduation. Sticks are graduated in tenths and hundredths of inches of rain. An inch of water equals only one-tenth of rain because the funnel top of the gauge concentrates ten times the actual rainfall into the measuring tube.

The rain measuring stick will become dirty and greasy in time and the water line will not stand out sharply. When this occurs, a new stick should be requested. Sticks will last longer if they are not wiped with the hands. Do not use a homemade stick or ruler if the standard measuring stick is broken but order a new one.

The standard Weather Bureau gauge holds two inches of rain and will seldom run over between readings. The Forest Service type, however, holds only one-half inch in the measuring tube before it runs over into the larger container. When this happens, measure the amount of rain in the small measuring tube, empty it, pour the remaining water from the outside can into the tube, measure it, and repeat the process until all of the rain has been measured and totaled.

In regions where snowfall is likely at intervals through a winter fire season, the funnel top of the rain gauge should be left off to facilitate the catch of snow. Always melt snow and ice in the rain gauge and pour the water into the small inner tube before measuring in the regular way.

Recording Observations

Observations will be recorded on Form 14, Fire Danger Daily

Form 14
(Rev. Sept., 1939)

FIRE DANGER DAILY RECORD

Station________________ Forest________________ District________________

Month________________ Year________________ Observer________________

Day of Month	C.S.T. / E.S.T.			7 a.m. / 8 a.m.		1 p.m. / 2 p.m.		4 p.m. / 5 p.m.					No. days since last rain of 0.50" or more	Fire danger class
	Precipitation							Precipitation						
	Began	Ended	Amount	Wind velocity m.p.h.	Fuel moisture percent	Wind velocity m.p.h.	Fuel moisture percent	Began	Ended	Amount	Wind velocity m.p.h.	Fuel moisture percent		
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
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Record, (see accompanying sample) at most stations but at cooperative Weather Bureau stations it is satisfactory to use Form 1009-D or 1009-E, standard forms furnished these few stations that supply weather measurements.

Three observations are recorded each day at 7 a.m., 1 p.m., and 4 p.m., Central Standard Time or 8 a.m., 2 p.m., and 5 p.m., Eastern Standard Time. While these hours are recommended, there may be reasons for changing them in some localities because of pressure of other work or similar reason. The form will accommodate one month's record. Headings should be completely filled in.

Precipitation. Precipitation is measured morning and evening. It is important to show time of beginning and ending of rainfall, in hours and minutes, and to put down the letters "a.m." or "p.m." as the case may be. For example, 11:10 a.m. to 1:15 p.m. If it is raining at the time of measurement, put "cont." (for "continued") in the column "ended". Then at the next measurement show the time the rain ended. As an illustration, suppose it began raining at 6 a.m. and rained until 11 a.m. The record of time of precipitation would be:

8 a.m. reading (began 6 a.m.
(ended (cont.)

5 p.m. reading (began ------
(ended 11 a.m.

If rain or snow occurs during the night and the time of beginning and ending is unknown, put "DN" in these spaces to signify "during night". If intermittent showers occur, write "showers" and show the time of ending of the final shower.

If the amount of rain is less than 0.01 inches and is too small to measure, enter "Trace" in the amount column. If just a few drops of rain fall, it should be shown as a trace.

Wind. Average winds obtained from buzzer counts are entered in the proper columns on Form 14 three times each day. If a dial-type anemometer is used, the dial readings may be entered under "wind velocity" and the average miles per hour entered in the right margin.

Fuel Moisture. Three daily readings of wood stick moisture are entered as shown. At cooperative Weather Bureau stations where Form 1009-D or 1009-E is used, one of the blank columns can be headed "fuel moisture" and the proper readings entered there.

Ordinarily the observer will not need to fill in the "days

since rain" column or be required to determine class of fire danger unless he serves as fire dispatcher as well. For example, a lookout man who operates a danger station and functions as a dispatcher for his territory would desire to fill out completely these last two columns on Form 14. In such cases, the observer is referred to "Instructions for dispatchers" given below.

Number of Forms. The number of copies of Form 14 that should be kept is left to the discretion of the forest officer responsible for the operation of the fire danger station. Ordinarily, at least two copies are desired. The Weather Bureau usually asks that Forms 1009-D and 1009-E be made out in triplicate.

Instructions for Dispatchers

Ordinarily it will be the dispatcher's or similar individual's job to assemble complete fire danger records daily from each danger station on his district, summarize them, and keep an up-to-date record of the fire danger class for the current day and that predicted for the next. Only in this way can the necessary organization changes be made quickly and effectively.

Summary of Danger Records

Dispatchers will find the Fire Danger Summary, Form 15, a convenience in assembling data from two or more danger stations and in rating fire danger. This is a daily form and space is provided for the entry of measurements made at four stations, as will be noted from the sample copy accompanying these instructions.

At the close of each day (or at intervals during the day if desired) the dispatcher should communicate with the fire danger observers and obtain the complete records taken at the three periods of observation. These are summarized in the lower portion of the table and a rating of fire danger class for today and tomorrow at each station and for the district as a whole is obtained. District danger ratings should be made from averages of moisture, wind, and rain at the several stations and not be obtained by averaging the danger classes for each station.

Precipitation. Most of the lines in the summary are self-explanatory. When tallying "days since last rain of 0.50 inches or more", however, care must be used. If several rains occur that are not separated by drying weather, they should be lumped together and called one rain for purposes of figuring days since rain. For example, suppose it rained 0.38" yesterday afternoon and 0.20" this morning, stopping at 11 a.m., when it cleared and the sun came out. Since no

Form 15
(Rev. Sept. 1939)

FIRE DANGER SUMMARY

______________________ Forest

These data for the period (beginning ______ PM ______ (Day)) ______ (Month) ______ (Year)
(ending ______ PM ______ (Day))

Time of obser-vation		Factor measured		Station				District totals or averages		
CST	EST									
7 am	8 am	Precipitation	began							
			ended							
			amount							
		Wind velocity, m.p.h.								
		Fuel moisture, percent								
		Fire danger class								
1 pm	2 pm	Wind velocity, m. p. h.								
		Fuel moisture, percent								
		Fire danger class								
4 pm	5 pm	Precipitation	began							
			ended							
			amount							
		Wind velocity, m.p.h.								
		Fuel moisture, percent								
		Fire danger class								
Summary		Total rain since last reading yesterday						Condition of vegetation		
								Green	Trans.	Cured
		No. days since last rain of 0.50" or more								
		Av. p.m. wind velocity								
		Lowest fuel moisture								
		Visibility distance, miles								
		Class of organization on duty								
		Fire danger class	today							
			tomorrow							

pronounced drying could have occurred during the night between the two rains, for all practical purposes the amount of the last rain has been 0.58". If "today" had remained cloudy and foggy, zero days since rain would be shown for today. When intermittent showers extend over a period of a day or more and they total at least 0.50" they should be called one rain.

It is emphasized that all distinctly separate small rains and showers that total less than 0.50" are disregarded in summarizing days since rain.

If snow covers the ground at the time of observation, put a letter "s" in the line "days since last rain of 0.50" or more". Fire danger should always be rated class 1 when snow covers the fuels. When measurements are to be commenced in the spring at a station where snow has recently melted the number of "days since rain" should be counted from the day of snow melt rather than the last day of snowfall or of rain. Of course, the melting snow is as effective in wetting fuels as an equivalent amount of rain.

Wind. Average afternoon wind velocity is recorded in the summary. If a station reports in miles per hour, the two afternoon readings are averaged. If a station is equipped with a standard Weather Bureau anemometer and reports dial readings, average afternoon velocity is determined by subtracting the smaller from the larger value and dividing by the number of hours between the two readings. The morning wind reading is not used in the summary but dispatchers will find that this early observation often will indicate to them the occurrence of what will develop into a windy day.

Fuel Moisture. The lowest fuel moisture for the afternoon is shown in the summary. Sometimes the early morning fuel moisture actually will be the lowest because of late morning or afternoon showers. In such an occasional case, this low morning fuel moisture has little signifificance because of the greater importance of afternoon conditions.

Condition of Vegetation. Since there is no exact way to measure condition of vegetation, certain indices combined with the best judgment of the field men are relied upon to determine the status of this factor. It will usually be the dispatcher's responsibility to procure this information from the best sources and enter it currently on Form 15 by circling one of the three possibilities, green, transition, or cured, shown in the right-hand column, first line of the summary.

In all cases the condition of lesser vegetation will be classified; that is, grasses, weeds, and shrubs as distinct from trees. The classification "green" is used from the time when grasses, weeds, and

shrubs become one-half to three-quarters grown, continuing through the summer until they are cured by fall frosts. These changes usually coincide with the period when trees become more than three-quarters leafed out until the first fall frost causes noticeable and widespread coloration. The spring transition period extends from the time grasses and weeds begin to spring up in profusion until they are three-quarters grown. This period usually coincides with the time the tree leaves reach "the size of squirrels' ears" until trees are three quarters leafed out. The fall transition, shorter and more abrupt than the spring period, begins when the first fall frost causes curing of the lesser vegetation, and lasts until it is at least 90 percent cured. Tree leaves have usually begun to fall quite generally throughout the forest by the end of the autumn transition. The classification "cured" is easy to determine and is used for the remainder of the year. This period extends from that time in the fall when lesser vegetation is 90 percent cured, into the spring when grasses and weeds begin the period of rapid growth and tree leaves are "the size of squirrels' ears".

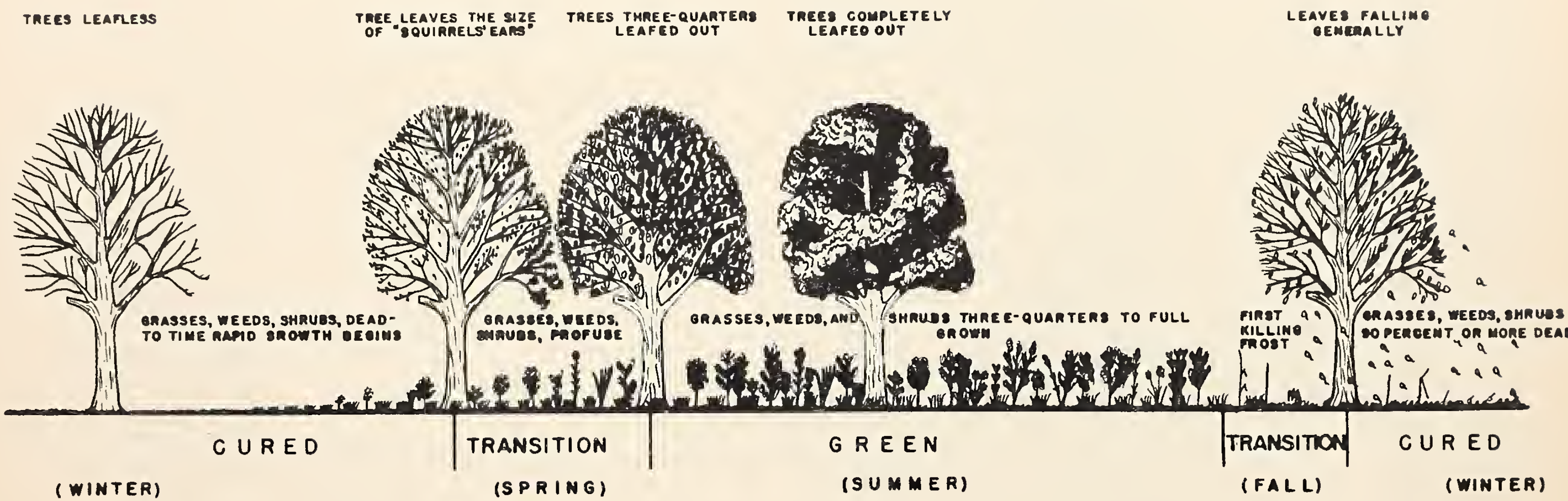
There must be exceptions to the general rules for determining condition of vegetation. For example, on areas where huckleberry brush predominates, curing may begin much earlier than elsewhere. In sedge grass fields where little else grows, the period "green" may first occur about mid July or early August. However, if care is used, the classification of <u>vegetation</u> <u>in</u> <u>general</u> can be made with little chance for error. The chart shown on page 40 may be of some assistance in this.

The greatest difficulty comes in mountain areas where elevation differences produce all three conditions simultaneously on a small area. In such a case the dispatcher should rate his district on the basis of vegetative condition in areas where risk is greatest. This will most likely be valleys and lower slopes in the East.

<u>Visibility</u>. When poor visibility accompanies high fire danger a different fire control organization becomes necessary. Perhaps more detectors must be put on the job or lookout men are sent out on planned patrols. Visibility distance is considered in prearranged organization plans. For this reason visibility measurements, from those stations equipped to measure it, should be entered daily in the line provided in the summary of Form 15, even though it is not used in figuring danger class.

<u>Class</u> <u>of</u> <u>Organization</u>. The class of fire control organization on duty may be entered in the summary if desired so that the dispatcher may have a current account of actual action taken each day in comparison with measured fire danger.

CLASSIFICATION OF CONDITION OF LESSER VEGETATION



Rating Today's Fire Danger

The front side of the fire danger meter is used to rate today's danger. Instructions for setting the single movable slide and reading the danger class are printed on the mountain and coastal plain danger meters.

The factors considered on the device applicable to the coastal plain or southern pine types are: (1) condition of vegetation, (2) average wind velocity, (3) number of days since 0.50" or more of rain, and (4) lowest fuel moisture content. The mountain or hardwood type meter adds to this list of variables, season of the year. Both rate danger on a scale of 1 to 5, one being the least severe class.

Rating Tomorrow's Fire Danger

A prediction of tomorrow's danger may be made by using the reverse sides of the meters. The procedure to obtain such a rating is identical with that given above except that predicted wind velocity is used and predicted state of weather substitutes for fuel moisture.

Predicted wind velocities are shown on the meters as very light, light, gentle, etc., the terminology used by the U. S. Weather Bureau in fire weather forecasts.7/ Predictions of wind velocity are necessarily made by the Weather Bureau to indicate more or less unrestricted regional air movement. Consequently, these forecasts can be made more useful when interpreted and modified to fit local forest conditions. By studying the relation of forecasts to actual winds on a particular ranger district, the accuracy of fire danger predictions can be increased.

The following Weather Bureau terms, used to describe state of weather, are arranged under the four headings with which they are used on the mountain danger meter. The columns headed "Partly cloudy" and "Fair" are combined on the coastal plain meter.

Precipitation	Unsettled	Partly cloudy	Fair
Rain	Unsettled	Partly cloudy	Fair
Snow	Cloudy	Decreasing cloudiness	Generally fair
Clearing			
Foggy	Mostly cloudy		Clear
Occasional rain or snow	Overcast		
Local rain or snow	Threatening		
General rain or snow			
Showers			
Snow flurries			

7/Fire Weather Forecast Terminology, U. S. Dept. of Agr. Weather Bureau, 1937.

Some dispatchers have become proficient in forecasting danger by studying local weather and using the Weather Bureau forecasts and danger meter predicting mechanisms as guides to their judgment. This procedure is highly advisable after a man has obtained an understanding of fire danger.

Fire Danger Charting

It is desirable for the dispatcher to keep on an atlas-sized chart a detailed graphic account of current conditions and predicted danger so that the fire control personnel may be posted at all times. An 18-by-20-inch sheet of cross-section paper, 10 squares to the inch, is satisfactory and will have enough room on it to show for each day the rain, fuel moisture, wind, visibility, and fire danger today and tomorrow for a three months period.

A solid vertical bar should be used to show amount of rain when it occurs. The bar must be drawn on the date line and its height should correspond to the amount of precipitation.

Small crosses connected by straight lines will be used to show fuel moisture, wind velocity, visibility, and danger class for today and tomorrow.

The Appalachian Station has devised such a fire danger chart, Form 16, and sample copies may be requested. Federal Forest Service regions stock all fire danger forms at regional headquarters.

REFERENCES FOR FIRE DANGER STATION OBSERVERS AND DISPATCHERS

The following partial list of references is suggested for those who wish to read further on fire danger measurement and related subjects:

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8. JEMISON, GEO. M.
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